1,088,741

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

A Device for Emitting and Receiving Ultra-Sonic Vibrations

We, INSTITUT DE RECHERCHES DE LA SIDERURGIE FRANCAISE, a professional organization governed by French laws, of 185, rue President Roosevelt, Saint Germain-en-Laye (Seine & Oise), France do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a device for emitting and receiving ultrasonic vibrations and more especially to a device for use in the ultrasonic inspection control of solid products.

The ultrasonic energy emitted by such a device is able to propagate through a test piece with different kinds of wave-forms and some of these, such as the LAMB waves, propagate only at a particular angle of incidence between the device and the surface of the test piece and only within a narrow frequency band, depending on the thickness of the test piece. In such conditions, the ultrasonic waves emitted by a transducer at a fixed frequency and at a predetermined angle of incidence, can only propagate or travel through a test piece of substantially constant thickness. However, metallurgical products of hot-rolling processes, for instance, are of pronouncedly variable thickness. It would thus be necessary to adjust the frequency of the emitted waves or their angle of incidence, in accordance with the thickness of the test piece. In view of its high mechanical resonance, a single electro-mechanical transducer will only be suitable for propagating waves of a far too narrow frequency band. It would of course be possible to use a number of transducers of suitably differing resonant frequencies, each matched to a range of thickness values, or to conceive of transducers with a variable angle of incidence. The resulting inconveniences can easily be imagined, in particular for the continuous scanning of rapidly passing test objects. In particular, changing the transducer used would involve the necessity for repeated calibration of the scanning device for each transducer.

It is an object of the present invention to obviate or mitigate the aforesaid disadvantages.

The present invention is a device for emitting and receiving ultrasonic radiations including not less than two electromechanical transducers having different resonant frequencies, an inductive element in parallel with the transducers, the element together with the capacitances of the transducers forming at least part of a resonant system having a resonant frequency intermediate the resonant frequencies of the transducers, and a source of electrical energy.

The present invention introduces significant improvements in ultrasonic scanning devices for scanning products of variable thickness, as is frequently the case for products of the iron and steel industry.

As will be appreciated, the device according to the invention allows for the emission of ultrasonic waves of appropriate amplitude within a sufficiently wide frequency band in order that the changes in the angle of incidence of the ultrasonic waves and the thickness of the test piece(s) shall not seriously influence the propagation of the ultrasonic radiation through the test piece. The ultrasonic radiation emitter is excited by pulses and, if the width of the pass-band is sufficient, there will always be among all the frequencies emitted a frequency band capable of passing through the test piece at any one time, even if the thickness of the latter varies.

In order to obtain a wide band of utilisable frequencies, it is for instance possible to supply from the same electrical energy source, two different piezoelectric crystals connected in parallel, included in and forming part of an adjustable resonant system consisting of a self-inductance and a capacitance. It is thus possible to select frequencies situated between the two resonant frequencies of the said piezoelec-

[*Price 4s. 6d.*]

tric crystals and thus obtain a very wide, usable frequency band.

However, the use of such an adjustable resonant system also furnishes a further advantage; the ultrasonic energy absorbed by a body is variable according to the frequency, and the thickness of the particular body. The adjustment of the resonant frequency of such a system will enable some degree of compensation to be obtained, of the differences in the absorptivity of the test material by favouring the frequencies most highly absorbed. As a result, the sensitivity of detection of flaws will be quasi-constant over a range of thickness values which, using hitherto-known transducers, would require at least three different transducers each of which has to be separately calibrated.

Thus, a constant absorption is obtained, of the ultrasonic radiation of whatever frequency.

An embodiment of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 shows the essential principle of a piezoelectric arrangement in accordance with the present invention;

Fig. 2 is a perspective view of the same arrangement;

Fig. 3 shows the resonance curves of the two piezoelectric crystals and a resonant circuit;

Fig. 4 reproduces the curve of the resultant pass-band of the assembly of the two, piezoelectric crystals and the resonant circuit;

Fig. 5 shows the ultrasonic energy emitted by the transducer, depending on the frequency;

Referring to the drawings, Fig. 1 shows the circuit diagram of a device for the ultrasonic testing of defects in hot-rolled sheet or strip.

In this arrangement, two piezoelectric crystals 1 and 2 are supplied in parallel from a pulse generator 3 of known kind, through a circuit 4. The circuit conductors 4 are soldered on metallized faces 5a, 5b, 6a, 6b of the crystals 1 and 2. The same circuit 4 incorporates in parallel an inductance represented by a self-inductance coil 7 and a capacitance represented at 8, consisting of the capacitances of the piezo-electric crystals plus the parasitic capacitances of the connections.

When the generator 3 supplies electric pulses, the crystals 1 and 2 vibrate, each in its natural resonance frequency; the self-inductance 7 can be adjusted to form, with the capacitance 8, a circuit resonating at an intermediate frequency, so that the intermediate frequency band is favoured.

Fig. 2 shows a perspective sketch of the arrangement. This includes the crystals 1 and 2, supplied in parallel from the generator 3 through a circuit 4. The crystals 1 and 2 are cemented on a "Perspex" wedge 9 which transmits the vibrations to the test piece being scanned at the required angle of incidence ("Perspex" is a registered Trade Mark). A coaxial cable 10, forming part of the circuit 4, connects the pulse generator 3 with the transducer. The capacitance does not appear on this figure, since it consists principally of the capacities of the crystals 1 and 2 and of the coaxial cable 10. The metallized faces 5a and 6a are interconnected by a conductor 11; the faces 5b and 6b are interconnected by the conductor 12. The induction coil 7 is connected between the conductors 11 and 12. In the present embodiment its value is about 3 microhenrys: it contains about 20 turns of 0.25 mm wire wound together and with a coil diameter of 6mm. It is held in place only by its connections. The coaxial cable 10 comprises an external sheath 13 and a central conductor 14.

Fig. 3 shows the individual resonance curve A of the crystal 1, and the individual resonance curve B of the crystal 2; Curve C is the resonance curve of the resonant system formed by the self-inductance 7 and the capacitance 8.

Fig. 4 shows the curve D of the pass-band resulting from the combination of the two crystals and the resonant circuit. It will be seen that the total pass band D of the composite device is considerably wider than the bands of each of the crystals, while its efficiency is still perfectly satisfactory. For instance, if the normal resonant frequencies of the crystals 1 and 2 are, respectively, 1.1 and 1.6 Mc/s, the arrangement will provide a frequency range usefully extending from 0.9 to 1.8 Mc/s approximately, by which means LAMB waves can be used to scan articles of a thickness varying between 1.5 and 4.7 mm.

It may thus be assumed that, contrary to scanning by echo reflexion in the conventional manner, the device is practically aperiodic (dead-beat) in the useful band, and it is the test piece being scanned which imposes its natural frequency of vibration.

It is possible to favour certain frequencies which are less well transmitted or more highly absorbed by the test piece in question, and thus to maintain a sensitivity of detection of practically constant level. For example, Fig. 5 shows the curve of a device embodying the invention, which favours the higher frequencies. The crystal with the higher resonant frequency has a larger surface area, in such manner that its emitted energy is also greater. The curve is adjusted by regulating the resonant frequency of the circuit 7, 8 in such manner as practically to approach the required curve profile. This would evidently not be possible with a transducer of the conventional type.

The embodiment of the invention described above increases the possibilities of application of ultrasonic transducers by making them available for a larger range of test-piece thicknesses. Similarly, it enables the compensation

of the varying absorption of different materials to be tested, by the possibility of favouring the frequencies most readily absorbed by the material in question, in view of its extended frequency range.

The sensitivity of the arrangement is thus quasi-constant for a range of thickness values which, in the case of hitherto known ultrasonic transducers, would require the use of at least three different transducer units, each of which would require to be separately calibrated.

It is thus evident that the device of the invention need not be restricted to the applications already mentioned, nor to the detection of flaws in flat, metal products, but is equally applicable to the detection of discontinuities in all materials permeable to ultrasonic radiation. Similarly, the device of the present invention is not restricted to the detection of internal flaws, but may equally be used for the inspection of surface defects.

WHAT WE CLAIM IS:—

1. A device for transmitting and receiving ultrasonic vibrations including at least two parallel connected electro-mechanical transducers having different resonant frequencies, an inductive element in parallel with the transducers, the element together with the capacitances of the transducers forming at least part of a resonant system having a resonant frequency intermediate the resonant frequencies of the transducers, and a source of electrical energy.

2. A device as claimed in claim 1, in which the transducers are piezoelectric crystals.

3. A device as claimed in claim 1 or claim 2, in which the transducers are mounted on a common transmitting wedge.

4. A device as claimed in any of the preceding claims, in which the resonant frequency of the resonant system is variable.

5. A device as claimed in any of the preceding claims, in which the resonant system includes a capacitor in parallel with the inductive element.

6. A device for emitting and receiving ultrasonic vibrations substantially as hereinbefore described with reference to and as illustrated by the accompanying drawings.

H. D. FITZPATRICK & CO.,
Patent Agents,
5 Park Gardens, Glasgow, C.3, and
27 Chancery Lane, London W.C.2.

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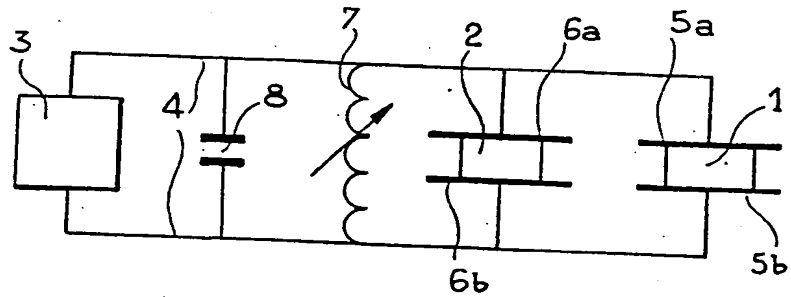
Fig 1



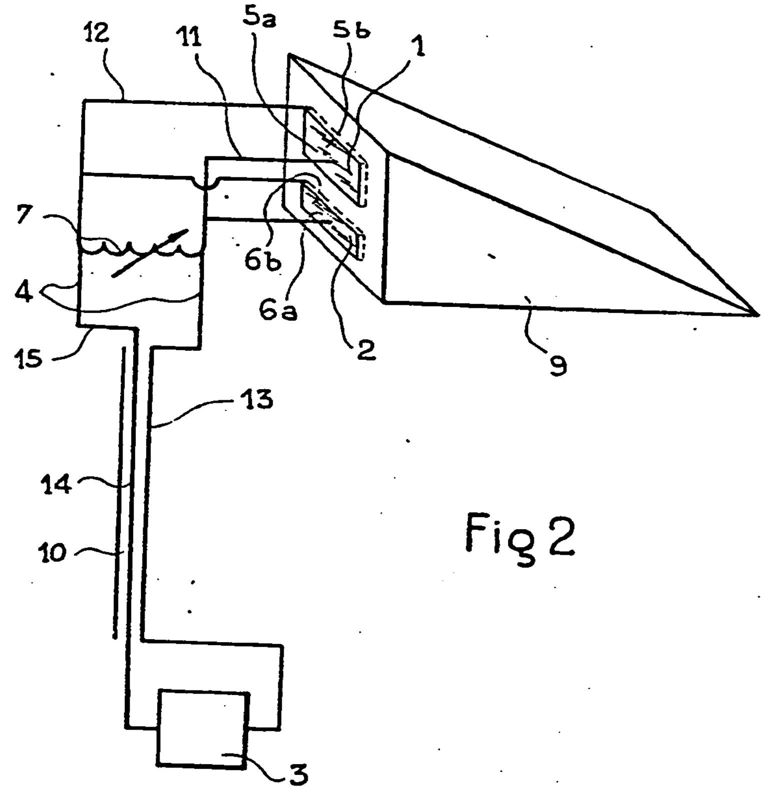


Fig 2

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2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

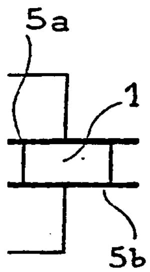
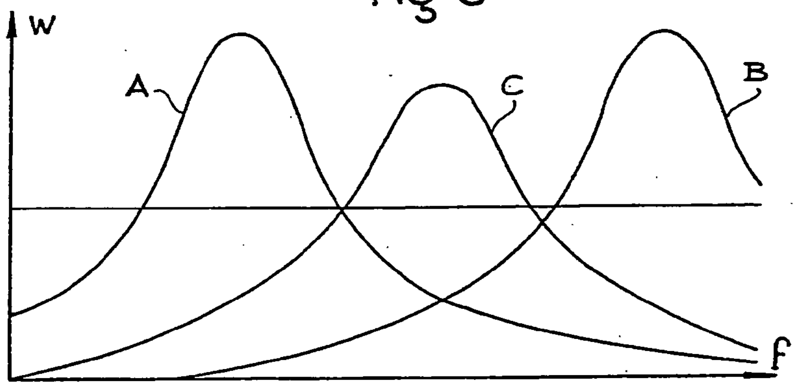


Fig 3



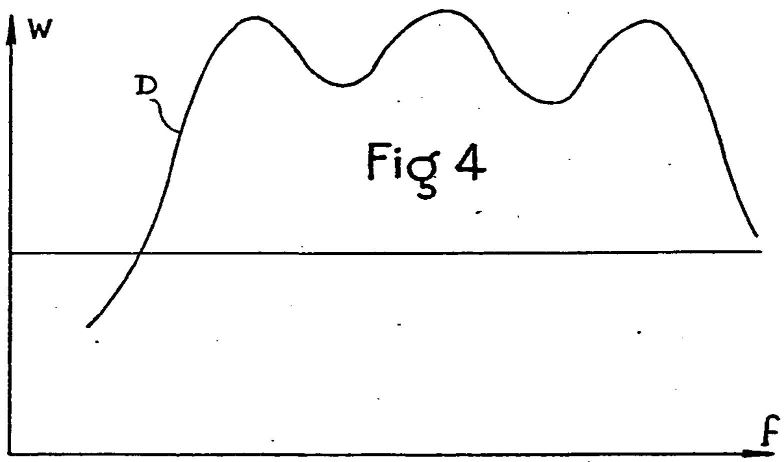


Fig 4

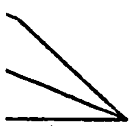
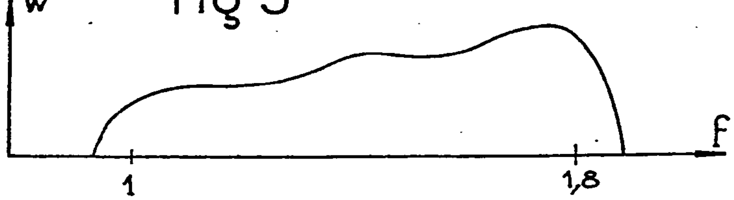


Fig 5



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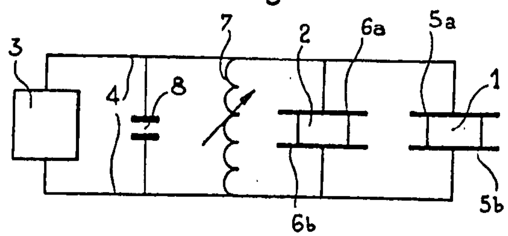
Sheets 1 & 2

Fig 1



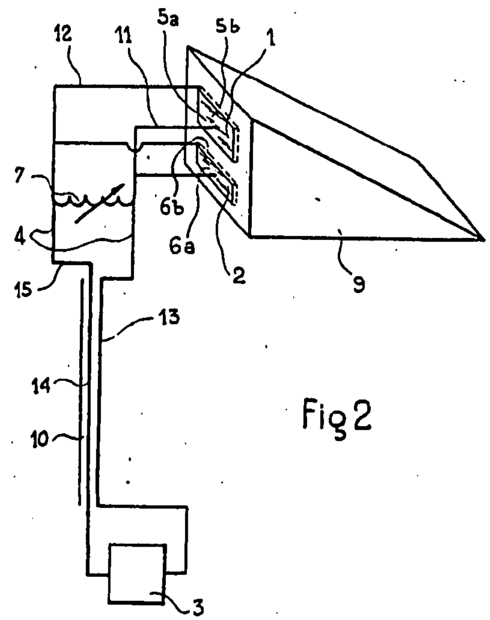
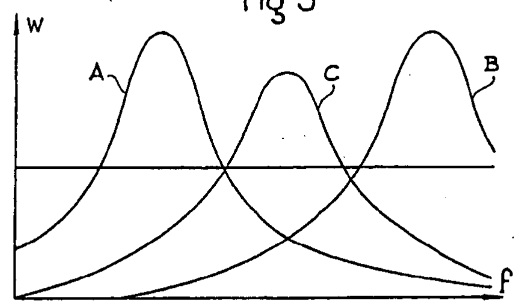


Fig 2

Fig 3



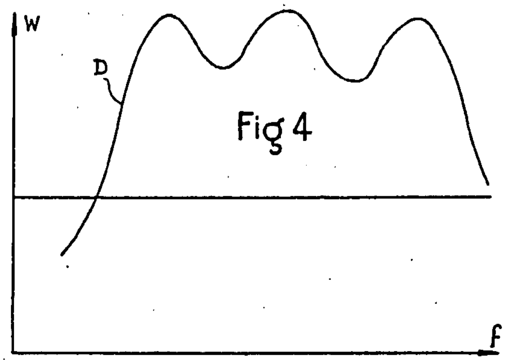


Fig 4

Fig 5